Wind Characteristics

Small Wind Systems Tutorial
Village Power Conference Workshop

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WINDPOWER

Part 4

Wind Energy

- **Created by Uneven Solar Heating**

- **Wind Energy is Kinetic Energy ... Mass & Momentum**

- **Wind Energy is Proportional to Velocity Cubed (V^3) ... If Velocity is Doubled, Power Increases by a Factor of Eight ($2^3 = 8$) ... Small Differences in Average Speed Cause Big Differences in Energy Production**

- **Wind Resources are Abundant**

- **Distributed ... Most Areas Have Sufficient Wind for Off-Grid Power Applications**
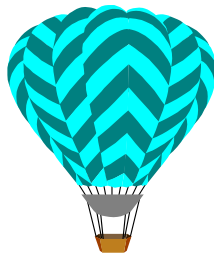
- **Wind is Intermittent**

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Power in the Wind (W/m²)

= 1/2 x air density x swept rotor area x (wind speed)³

ρ A   V³
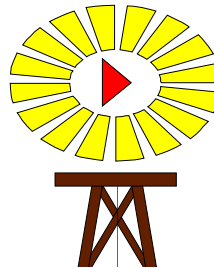
Density = P/(RxT)

P - pressure (Pa)
R - specific gas constant (287 J/kgK)
T - air temperature (K)

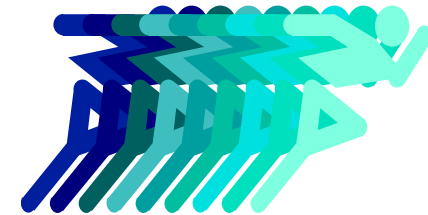**Area = $\pi\ r^2$**

**Instantaneous
Speed**

(not mean speed)

| kg/m³ | m² | m/s |

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Wind Shear
The change in horizontal wind speed with height

- A function of **wind speed**, **surface roughness** (may vary with wind direction), and **atmospheric stability** (changes from day to night)
- Wind shear exponents are higher at low wind speeds, above rough surfaces, and during stable conditions
- Typical exponent (α) values:
  - .10 - .15: water/beach
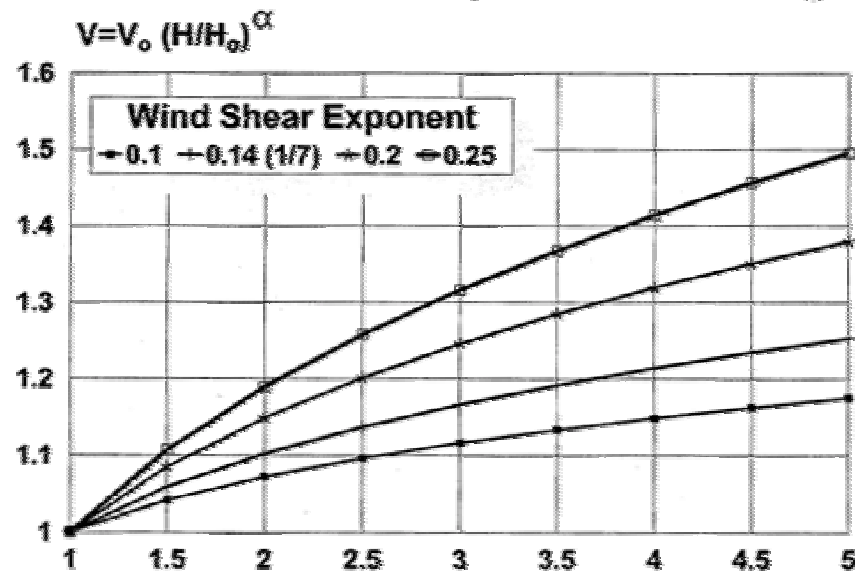 - .15 - .25: gently rolling farmland
  - .25 - .40+: forests/mountains

$V_2 = 7.8$ m/s

$Z_2 = 40$ m

$V_1 = 7.0$ m/s

$Z_1 = 25$ m

Wind Shear Profile

α
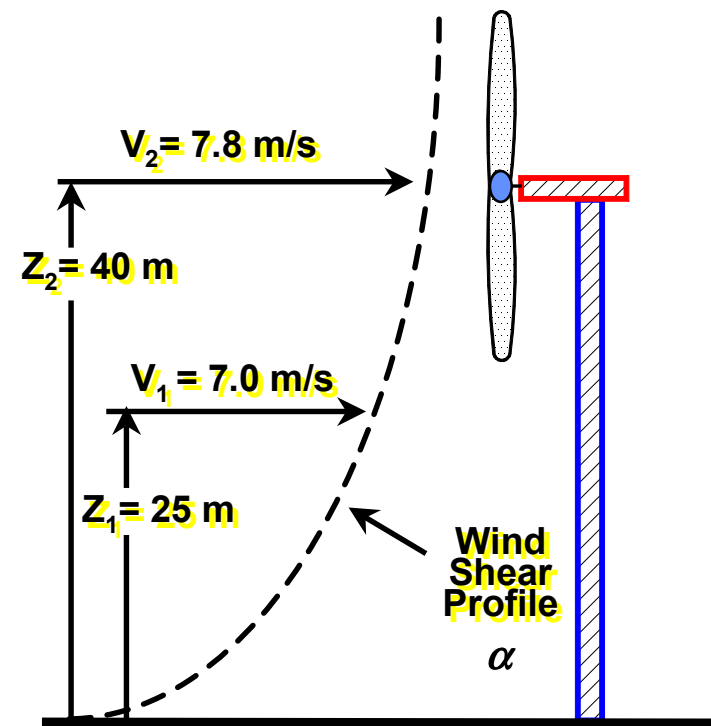
$$\alpha = \frac{\text{Log}_{10}[V_2/V_1]}{\text{Log}_{10}[Z_2/Z_1]} \qquad V_2 = V_1(Z_2/Z_1)^{\alpha}$$

Graphic courtesy of AWS Scientific

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Taller is Vastly Better
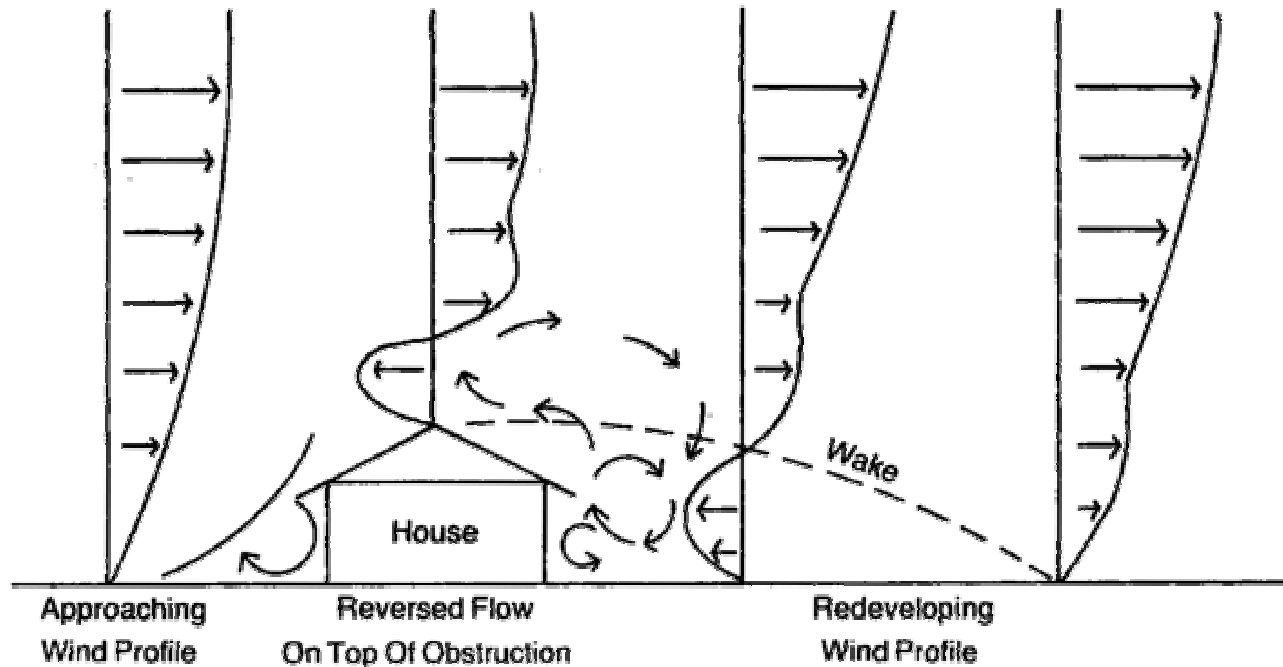
Increase in Wind Speed with Height

$$V = V_o (H/H_o)^\alpha$$

Wind Shear Exponent
0.1 0.14 (1/7) 0.2 0.25

Increase in Wind Power with Height

$$P = P_o (H/H_o)^{3\alpha}$$

Wind Shear Exponent
0.1 0.14 (1/7) 0.2 0.25

H/H_o

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Turbulence
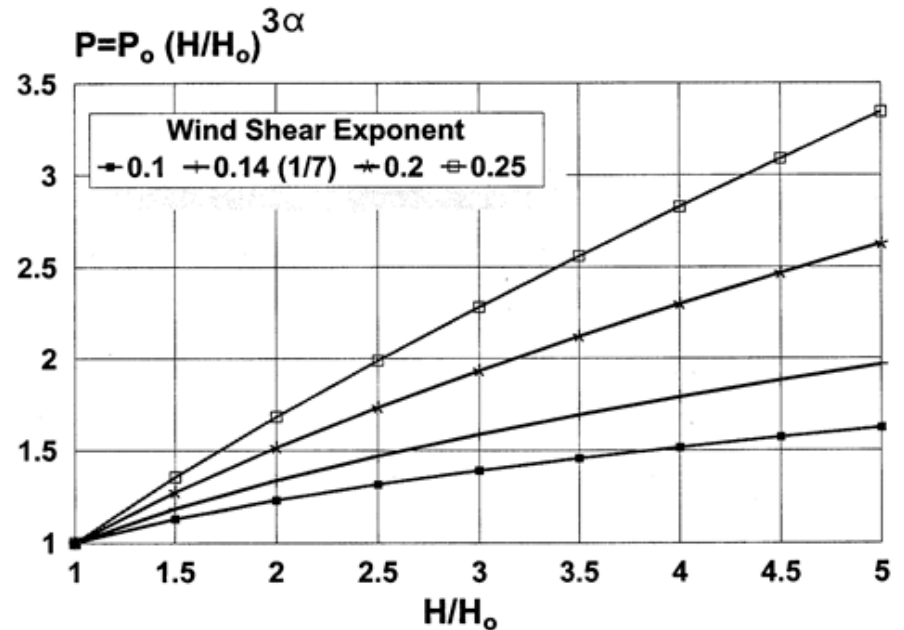
Approaching Wind Profile · Reversed Flow On Top Of Obstruction · House · Wake · Redeveloping Wind Profile

❖ **Turbulence caused by obstructions cuts performance**

❖ **Rule-of-Thumb: Be 30 ft. above obstacles within 300 ft.**

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Wind is Highly Variable

DC Currents May 15-21, 1993

Array Current   Inverter Current
Battery Current   Total Wind Current

Daily Variations

April Xcalac Data
Wind and PV on DC Bus

270 kWh avg, Wind and PV

60 kW Wind Array   11.7 kW PV Array

Daily Energy Output (kWh)

Day of the Month
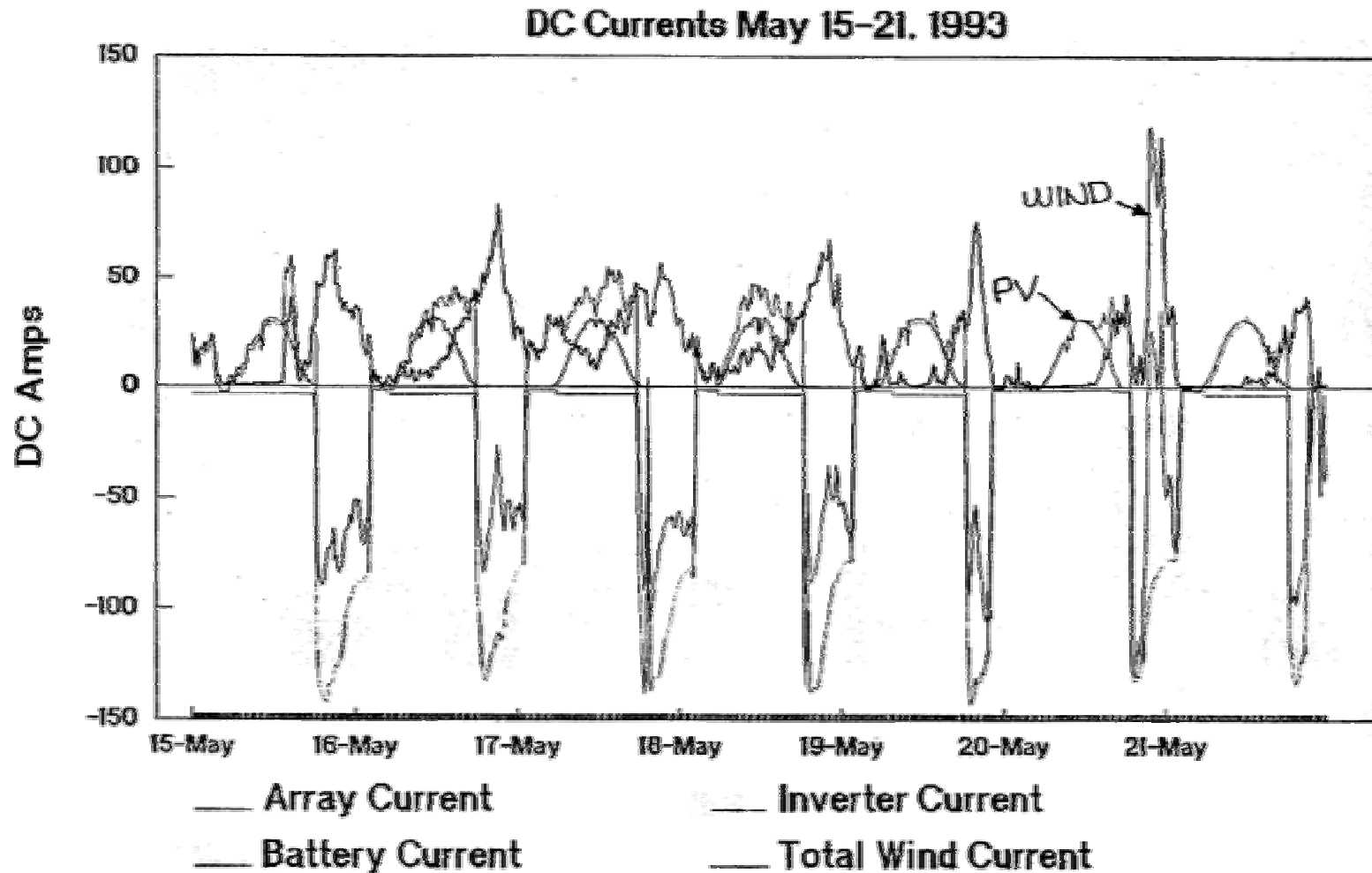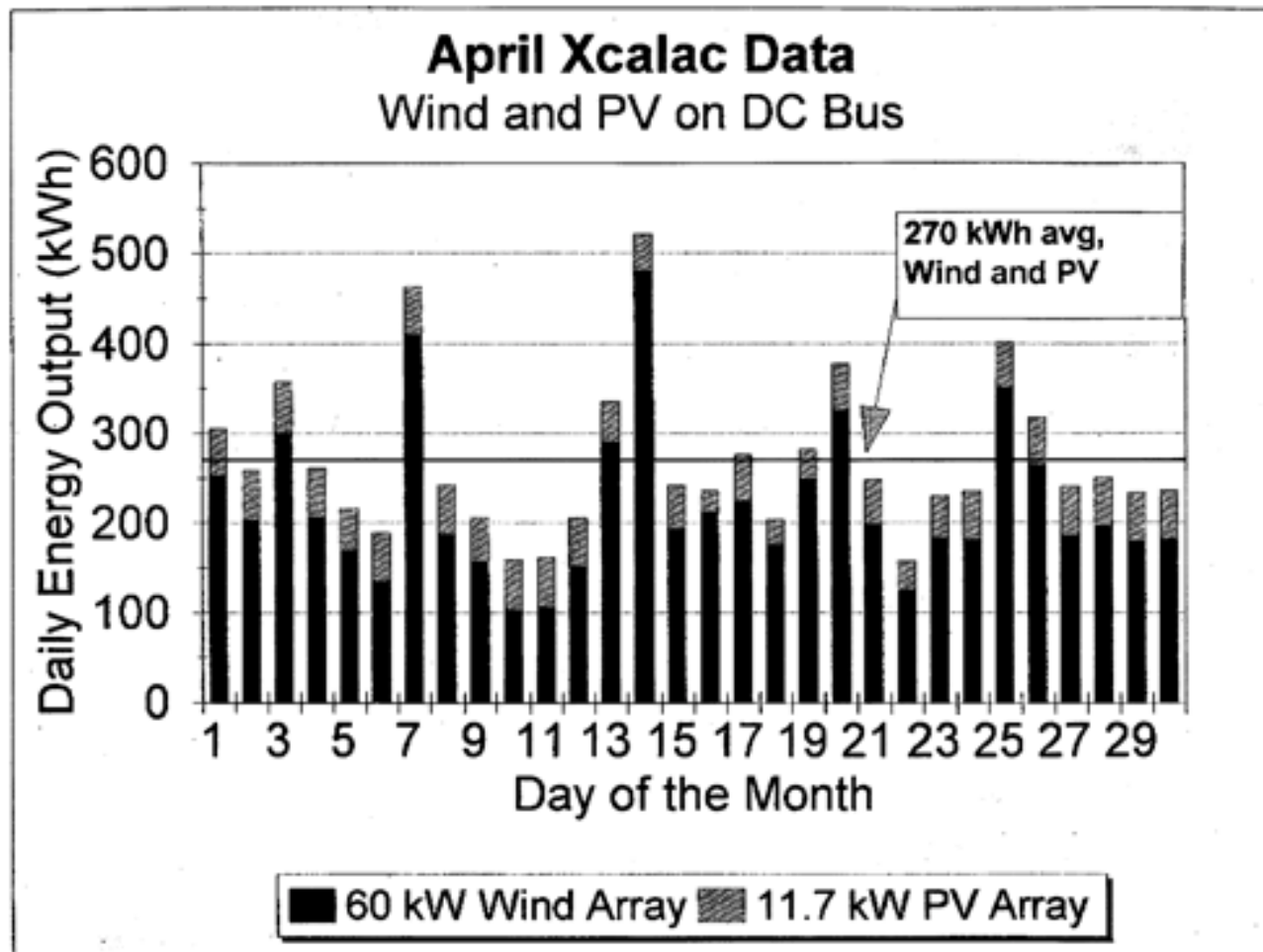
Seasonal and Annual Variations

Monthly Average Wind Speed
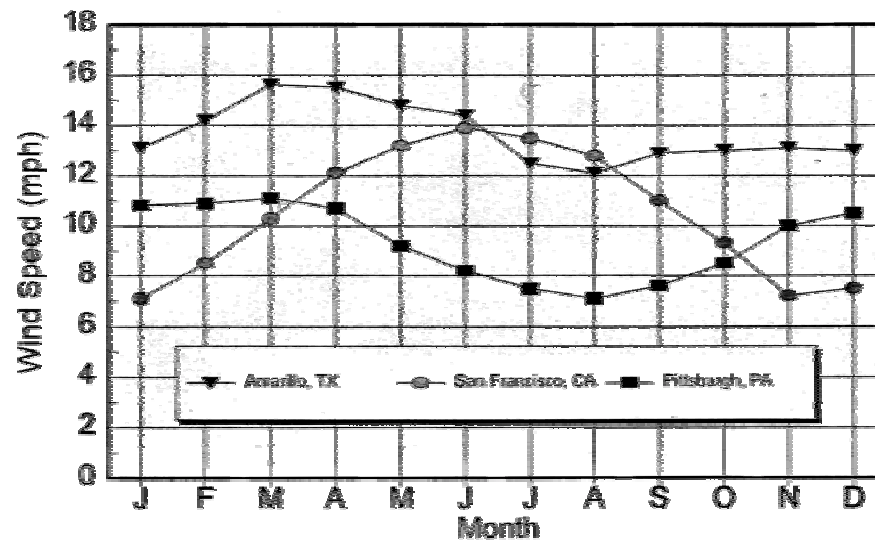
Month to Month

Year to Year
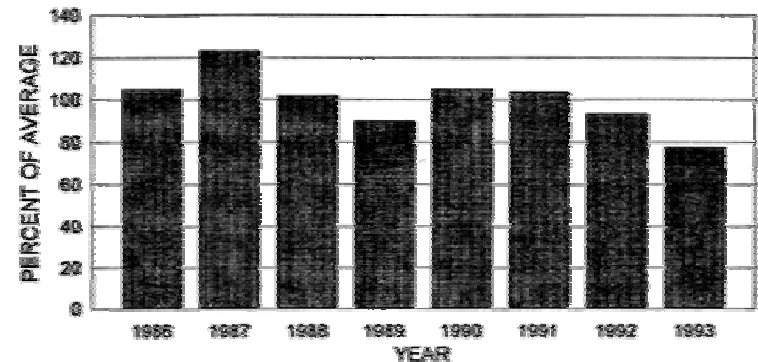
Wind Direction Patterns

❖ **Wind direction changes with weather front movements**

❖ **Sites have "Prevailing Wind Direction" … Useful in considering effects of obstructions and multi-turbine array layout**

❖ **Trade wind regimes can be essentially unidirectional**
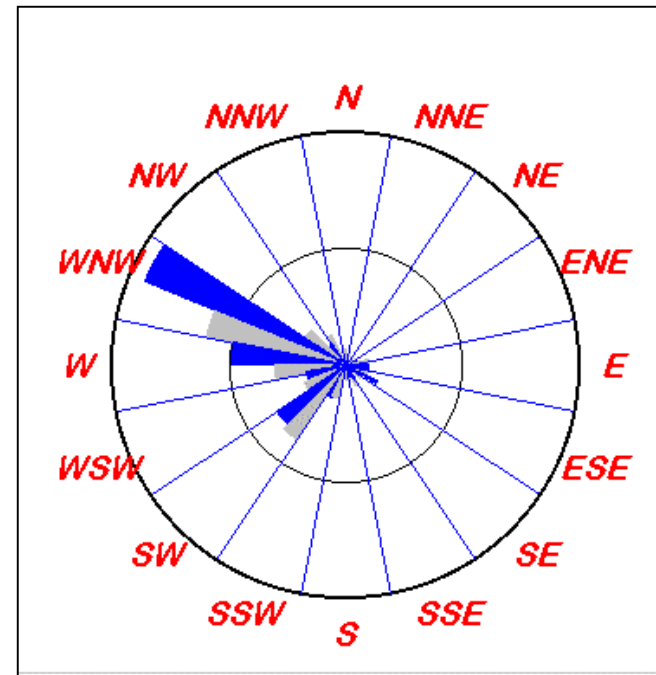
Dark wedges are energy weighted

Graphic courtesy of AWS Scientific